

1 1. A charge-coupled imager for imaging a sequence of image
2 frames, the imager comprising:
3 an array of super pixels disposed in a semiconductor substrate
4 having a surface that is accessible to incident illumination, each super
5 pixel including a plurality of independently-controlled subpixels, each
6 subpixel of a super pixel corresponding to a frame in the sequence of
7 image frames and each subpixel including:
8 a doped photogenerated charge collection channel region
9 opposite the illumination accessible substrate surface;
10 a charge collection channel region control electrode;
11 doped charge drain regions adjacent to the channel
12 region;
13 a charge drain region control electrode; and
14 a doped charge collection control layer in the substrate
15 below the charge collection channel region;
16 the charge collection channel region, the charge drain
17 regions, and the charge collection control layer each being characterized by a
18 dopant type and dopant concentration for expanding the charge collection
19 channel region in response to a charge collection control voltage applied to
20 the channel region control electrode, to collect in the charge collection
21 channel region photogenerated charge from the substrate during the image
22 frame corresponding to that subpixel, and for contracting the collection
23 channel region in response to a charge storage control voltage applied to the
24 channel region control electrode, to store the collected photogenerated charge
25 in the charge collection channel region and collect substantially no additional
26 photogenerated charge as other subpixels of the super pixel collect
27 photogenerated charge corresponding to other frames of the image frame
28 sequence.

1 2. The charge-coupled imager of claim 1 wherein the
2 semiconductor substrate comprises a p-type silicon substrate, the charge
3 collection channel region comprises an n-type region, the charge drain
4 regions comprise n-type regions, and the charge collection control layer
5 comprises a p-type layer.

1 3. The charge-coupled imager of claim 2 wherein the
2 semiconductor substrate comprises a p⁺ silicon substrate, the charge drain
3 regions comprise n⁺ regions, and the charge collection control layer comprises
4 a p⁺ layer.

1 4. The charge-coupled imager of claim 1 wherein the charge
2 collection channel region comprises a buried channel disposed adjacent to a
3 substrate surface opposite the illumination-accessible substrate surface.

1 5. The charge-coupled imager of claim 4 wherein the charge
2 collection control layer includes first sections that are at a first depth in the
3 substrate and located under a first section of the charge collection channel
4 region and all of the charge drain regions, and includes second sections that
5 are at a second depth in the substrate different than the first depth and
6 located under a second section of the charge collection channel region.

1 6. The charge-coupled imager of claim 1 wherein the charge
2 collection control voltage is selected to expand a depletion region of the
3 charge collection channel region into the substrate to a depth greater than a
4 depth of the charge collection control layer.

1 7. The charge-coupled imager of claim 1 wherein the charge
2 storage control voltage is selected to contract a depletion region of the charge
3 collection channel region into the substrate to a depth less than a depth of
4 the charge collection control layer, and wherein a charge drain control
5 voltage is selected to expand a depletion region of the charge drain regions to
6 a depth greater than a depth of the charge collection control layer.

1 8. The charge-coupled imager of claim 1 wherein the illumination-
2 accessible substrate surface is a back side of the substrate and wherein the
3 control electrodes are disposed on a front side of the substrate.

1 9. The charge-coupled imager of claim 1 wherein the charge
2 collection channel region control electrode comprises three electrodes
3 corresponding to three-phase photogenerated charge collection by the charge
4 collection channel region.

1 10. A charge-coupled imager for imaging a sequence of image
2 frames, the imager comprising:
3 an array of super pixels disposed in a semiconductor substrate
4 having a surface that is accessible to incident illumination;
5 a plurality of subpixels provided for each super pixel, each
6 subpixel corresponding to a frame in the sequence of image frames and
7 each subpixel including:
8 a doped photogenerated charge collection channel region
9 opposite the illumination-accessible substrate surface,
10 a charge collection channel region control electrode,
11 doped charge drain regions adjacent to the channel
12 region,
13 a charge drain region control electrode, and

14 a doped charge collection control region; and
15 a channel region control voltage connection provided to each subpixel on a
16 substrate surface opposite the illumination-accessible surface, each subpixel
17 channel region control voltage connection configured for independent
18 collection and storage of photogenerated charge from the substrate at the
19 charge collection channel region of a subpixel during a corresponding frame
20 in the sequence of image frames.

1 11. The charge-coupled imager of claim 10 further comprising a
2 drain region control voltage connection provided to each subpixel on the
3 substrate surface opposite the illumination-accessible surface, each subpixel
4 drain region control voltage connection being configured for drainage of
5 photogenerated charge from the substrate to a subpixel drain region in
6 response to a drain region control signal.

1 12. The charge-coupled imager of claim 10 wherein the subpixel
2 channel region control voltage connection is configured for collection and
3 storage of photogenerated charge from the substrate at the charge collection
4 channel region of at least two subpixels during a corresponding frame in the
5 sequence of image frames.

1 13. The charge-coupled imager of claim 10 wherein the subpixel
2 channel region control voltage connection is configured for subpixel-specific
3 weighting of collection and storage of photogenerated charge from the
4 substrate at each subpixel.

1 14. The charge-coupled imager of claim 10 wherein the subpixel
2 channel region control voltage connection is configured for control of the
3 correspondence between subpixels and image frames.

1 15. The charge-coupled imager of claim 10 wherein the subpixel
2 channel region control voltage connection is configured for independent
3 collection and storage of photogenerated charge from the substrate at the
4 charge collection channel region of a subpixel during a corresponding frame
5 in multiple sequences of image frames.

1 16. The charge-coupled imager of claim 10 wherein the subpixel
2 channel region control voltage connection comprises metal control signal lines
3 for delivering voltage control signals to the charge collection channel region
4 control electrodes and the charge drain control electrodes.

1 17. The charge-coupled imager of claim 16 further comprising
2 semiconducting isolation lines provided between the metal control signal
3 lines and the charge collection channel region control electrodes and the
4 charge drain control electrodes.

1 18. The charge-coupled imager of claim 10 further comprising a
2 serial output register connected to accept a sequence of image frame charge
3 from each super pixel after the image frame sequence is collected and stored
4 at each super pixel.

1 19. The charge-coupled imager of claim 18 further comprising a
2 column binning register connected to the serial output register image frame
3 data to accept and sum image frame charge from columns of super pixels.

1 20. The charge-coupled imager of claim 19 wherein the serial output
2 register and the column binning register are disposed in the semiconductor
3 substrate.

1 21. A charge-coupled imager for imaging a sequence of image
2 frames, the imager comprising:
3 an array of super pixels disposed in a semiconductor substrate
4 having a surface that is accessible to incident illumination; and
5 a number of subpixels provided for each super pixel, each
6 subpixel of a super pixel corresponding to a frame in the sequence of
7 image frames and each subpixel including:
8 a doped photogenerated charge collection channel region
9 opposite the illumination-accessible substrate surface;
10 a charge collection channel region control electrode;
11 doped charge drain regions adjacent to the channel
12 region;
13 a charge drain region control electrode; and
14 a doped charge collection control region;
15 the number of subpixels included in each super pixel being selected
16 based on length of image frame sequence and frame rate, to collect
17 photogenerated charge from each frame in the image frame sequence by at
18 least one corresponding subpixel of the super pixel and store the collected
19 charge at the corresponding subpixel as other subpixels collect
20 photogenerated charge from other frames in the image frame sequence.

1 22. The charge-coupled imager of claim 21 wherein the number of
2 subpixels is selected based further on charge collection efficiency that is
3 characteristic of photogenerated charge in the substrate, for collecting
4 substantially all photogenerated charge from the substrate at prespecified
5 subpixels during a corresponding frame.

1 23. The charge-coupled imager of claim 21 wherein the number of
2 subpixels is selected to collect and store at the super pixel each frame of the
3 image frame sequence before transferring the image frame sequence from the
4 super pixel.

1 24. The charge-coupled imager of claim 21 wherein the number of
2 subpixels comprises at least two subpixels corresponding to each frame in the
3 image frame sequence.